# Foreign patents surge and technology spillovers in China: evidences from the patent market and trade market in 1985-2009

**ABSTRACT：**

The paper investigates the determinants of foreign patent surge and the effects of technology spillovers in China based on an industry-level sample of 19 countries and regions from 1985 to 2009. We explore two hypotheses to explain the increasing foreign propensity to patent and the effects of technology spillovers in China, the market covering hypotheses and competitive threat hypotheses. The results show strong support for the competitive threat hypothesis. However, the foreign patenting surge in China does not mean China has more access to outsource advanced technology; on the contrary the technology spillover from foreign countries in China is limited.

**Keywords:** foreign patents, market cover, competitive threat, technology spillover, technology proximity, China

## 1. Introduction

Over the past two decades, global patenting practice appears to have been active, with a 9% annual growth rate by U.S. Patent and Trademark Office (USPTO) patent applications (USPTO, 2007), and nearly 35% by China's State Intellectual Property Office (SIPO) patent applications (SIPO, 2010). Since the growth of foreign patent applications by SIPO is far more than that in the foreign inventors' home countries, it seems that China has become the country with the best patent protection for foreign inventors. From 1993 to 2008, the top five foreign countries patents granted in China were Japan, the United States, Germany, South Korea and France (accounting for 80% of all total foreign patents), and the average annual growth rate for the five countries was 17.45% by SIPO, comparing to only -3.83% by USPTO. However, in 1986-1992, the five countries' USPTO patent granted growth rate (3.13%) was higher than that of SIPO (0.77%), as shown in Table 1. Moreover, there are several obvious national and industrial level features of the foreign patent applications and grants in China. In term of national patent distribution, there was a rise in the number of countries applying for patents in China and granted patents by SIPO, from 66 in 1988-1992 to 135 in 2010, but there existed a predominantly concentration in several countries. From 1985 to 1992, the top five countries accounted for 87.7% of all patent grants, but in period of 2002-2010, the figure increased to 95.6%. In term of industrial patent distribution, the top five countries identified above showed some differences between SIPO and USPTO.

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2007), and nearly 35% by China's State Intellectual Property Office (SIPO) [①]patent applications (SIPO, 2010). Since the growth of foreign patent applications by SIPO is far more than that in the foreign inventors' home countries, it seems that China has become the country with the best patent protection for foreign inventors. From 1993 to 2008, the top five foreign countries patents granted in China were Japan, the United States, Germany, South Korea and France (accounting for 80% of all total foreign patents), and the average annual growth rate for the five countries was 17.45% by SIPO, comparing to only -3.83% by USPTO. However, in 1986-1992, the five countries' USPTO patent granted growth rate (3.13%) was higher than that of SIPO (0.77%), as shown in Table 1. Moreover, there are several obvious national and industrial level features of the foreign patent applications and grants in China. In term of national patent distribution, there was a rise in the number of countries applying for patents in China and granted patents by SIPO, from 66 in 1988-1992 to 135 in 2010, but there existed a predominantly concentration in several countries. From 1985 to 1992, the top five countries accounted for 87.7% of all patent grants, but in period of 2002-2010, the figure increased to 95.6% and remained relatively stable in the following years. In term of industrial patent distribution, the top five countries identified above showed some differences between SIPO and USPTO.

Table 1. The growth rate of patent applications for five countries in USPTO and SIPO

| | USPTO | SIPO |
|---|---|---|

[①] Following a recent restructuring, the former State Intellectual Property Office of China (SIPO) was renamed to China National Intellectual Property Administration, abbreviated as CNIPA, on 28 August 2018.

| Country | 1986-1992 | 1993-2001 | 2002-2008 | 1993-2008 | 1986-1992 | 1993-2001 | 2002-2008 | 1993-2008 |
|---|---|---|---|---|---|---|---|---|
| France | 1.63% | 2.78% | -24.95% | -10.76% | 1.85% | 20.48% | 7.92% | 16.20% |
| Germany | -0.05% | 5.16% | -23.35% | -8.92% | 0.83% | 18.36% | 11.73% | 16.05% |
| Japan | 4.54% | 4.87% | -19.11% | -6.46% | -2.85% | 26.41% | 8.43% | 20.39% |
| Korea | 38.17% | 16.01% | -13.21% | 3.56% | 31.03% | 25.19% | 11.78% | 22.09% |
| US | 2.81% | 6.83% | -13.48% | -2.63% | 1.87% | 16.50% | 10.13% | 13.95% |
| Five-countries Average② | 3.13% | 6.29% | -15.36% | **-3.83%** | 0.77% | 21.27% | 9.50% | **17.45%** |
| China③ | 14.36% | 26.65% | 7.91% | 20.68% | 13.70% | 8.43% | 24.72% | 17.49% |

Sources: OECD patent statistical database and the SIPO website.

The sharp increase of foreign patent applications in China causes our study seek to develop an approach to solve a significant patents surge puzzle: why are foreign investors keen to apply for patents in China? Furthermore, the desire for advanced technology in China is reflected in the pursuit of patents. It seems to ignore the more important issues of foreign patenting in China: does this phenomenon of foreign patenting surge in China mean more technology spillovers? China as the research context for our study is considered to be more uncertain and unpredictable (Burgers & Padgett 2009). The gradual development of China's legal intellectual property regime (Howse, 2011), the largest FDI recipient (Peng, 2006) and the Chinese trade market provides a unique environment for the patents surge and an excellent research context to capture the complexity of foreign patents surge and technology spillovers.

To address this research gap, this study investigates two hypotheses: the market covering hypothesis and competitive threat hypothesis, to analysis the increasing foreign propensity to patent in China and argues the possible effects on technology spillovers in the perspective of

② The average is five- countries weighted average, where weight is the proportion of the number of patent application.

③ China refers to Mainland China, which does not cover Hong Kong, Macau and Taiwan, where different economic and legal systems are in operation, despite the fact that they are legally recognized as indispensable parts of the State of China

technology proximity. This research provides new insights on foreign patent surge and the effects of technology spillovers in emerging market. We contribute theoretically to the extant literature on Propensity to Patent (Hu, 2009) by integrating technology proximity on spillovers and competition and China's Foreign Patenting Surge. Meanwhile, we contribute methodologically via merging all the industry level patents in China from SIPO and USPTO covering 19 countries and regions from 1985 to 2009 comparing fix effects (FE) and generalized method of moment (GMM) panel analysis for the scenario. In response to the contributions on practice, patents surge in China is a significant and growing economic phenomenon that is of timely concern to policymaking and managers who can take the two conditions into consideration the relationship between foreign patents and technology spillovers in Chinese market.

## 2. Literature Review

The explosive growth of foreign patents in China has attracted economists' and innovation scholars' attention (Wu and Liu, 2004; Yang and Clarke, 2005; O'Keeffe, 2005; Hu & Jefferson, 2009; Li, 2009). Hu and Jefferson（2009）analysed the factors influencing foreign patent propensity in China, including foreign direct investment, conducive patent legislation and the reform of the ownership system. Zhang and Rogers (2009) argued that the rapid growth of foreign direct investment and trade contributed to the increase of foreign patents in China. Hu (2010) viewed the sharp increase of foreign patents as a reaction to the continuous encouragement and support for domestic innovation under the Chinese national innovation system. Liu and Chen (2010) and Sun (2008) also discussed the effects of various factors on

growth of foreign patents in China, such as technical innovation ability, investment and trade.

The motivation for applying for a patent in foreign countries has been in extensive discussion. Factors influencing foreign patenting include the quality or value of patents, diffusion rate, patent cost and market size（Eaton & Kortum, 1999）. Foreign direct investment, imports, and geographical distance between countries are also important considerations for patent application in a foreign country（Bosworth, 1980; Rashid, 2009）. Patent reform and related institutional changes, such as powerful fusion of the patent system and patent law, greatly inspire foreign patenting activities (Kortum & Lerner, 1999; Lerner, 2002). Private property protection, trade facilitation and the degree of marketization also influence international patent inflows (Xu & Chiang, 2005; Deng & Liao, 2010). In field of the modern international business, patent acts not only as an important source of profits, but also as a defense tool. Owning patents with the cutting-edge technology means more access to foreign markets (Cohen et al., 2002). The controls and trades concerning patents also strengthen companies' abilities of entering foreign markets. If two or more parties of the transaction have some specific advantage in a certain technical field, they are likely to form international strategic alliances, which would benefit the technical progress of international partners (Grindley & Teece, 1997; Cohen et al., 2000). New international business theory points out that as an international strategy foreign patenting depends on the company's understanding of international opportunities. For example, in order to ensure the relationship with suppliers and manufacturers, a company may use the patent license or cross licensing to enhance its negotiating power in the market (Oviatt & McDougall, 1994; Knight & Cavusgil, 1996; Bell

et al., 2004).

Influenced by these studies to a large extent, some new trends have appeared in the researches on the foreign patent surge in China. For example, Yang（2012）explained that the imitation and innovation threats from local domestic enterprises is an important reason for foreign patenting in China. Keupp et al. (2010) argued that the driving forces of foreign patent applications in China are not only from industry level, but also from firm level. Based on the analysis of patents activities in 11 multinational corporates in China, Keupp et al. (2012) pointed out that there is no single dominant motivation for multinational companies to apply for patents in an emerging nation with weak intellectual property protection such as China. Obviously, there exist some important differences between the analysis at firm level and the one at national level (Sun, 2003; Hu, 2010, Hu & Jefferson, 2009). The complexity of firms' samples affects the explanatory power of the models used and the applicability of research conclusions. Besides, arguments regarding the institutional aspect have also highlighted that, although the international coordination process of intellectual property protection has accelerated, China's intellectual property protection is still not mature enough (Li, 2012; Keupp et al., 2012).

New international business theory has made us realized that it is not enough to just focus on country level analysis, and further complementary research on industry, even firm level is necessary. Also, theoretically, the system of Chinese intellectual property rights protection may not be fully mature, but the rapid development and substantial potentiality of Chinese patent market has provided a perspective for the study of patents strategies and decisions. In this paper,

we implement and enrich the market competitive threat theory as well as market covering theory by making use of industry level data of different countries. We analyze the competition situation of trade markets and patent markets, discuss the factors causing foreign patenting surge in local market, and conclude with proximity index analysis that this surge may have negative effects on technology spillover in China.

## 3. Hypotheses, Data and a Preliminary Analysis

### 3.1 Hypothesis development

Although foreign patenting may face risk in every aspect, such as application, translation, maintenance, infringement and implementation, it is necessary for foreign firms to protect local market sales and technical invention. Patent control can help to maintain a competitive advantage by updating the enterprise's core and peripheral technology (Eaton & Kortum, 1999). As foreign firms are accelerating entry into the Chinese market via various ways, including trade, license and direct investment, the risk of their intellectual property being imitated increases. At the same time, the demand to bring the latest and the most advanced technology into Chinese market is also growing. All these integrating into the Chinese market leads to continual increase in the patenting tendency in China, which is the market covering hypothesis. The bigger market share or covering in the Chinese local market, the more a foreign firm patents in China. The larger market share means the higher possibilities of products or services exposure to the local market, and perhaps the higher risks of being imitated. However, the competitive threat hypothesis suggests that the willingness of a foreign company to apply for a patent in China depends on its competitors' patent decisions (Cohen, 2000). Patent application in China can help a foreign company ensure returns in the Chinese market from a

specific technology. The returns or the premiums depend on whether there exists a comparable technology from a competitive foreign firm or a Chinese local enterprise. Due to the more effective imitation and innovation from competitors, and the introduction of new technology in some other more active regions, foreign firms are likely to increase patent activity in China. To some extent, patent behavior of foreign firms in China is a response to the Chinese market and to the Chinese enterprises' patent behavior. Based on aggregate patent statistics, Hu (2010) found the competition threat hypothesis could explain foreign patent behavior in China. Based on survey data at enterprise level, Keupp et al., (2012) suggested these two hypotheses operated at the same time.

### 3.2 Data and sample

The sample in our paper involves 19 countries and regions; they are Australia, Austria, Canada, Denmark, Italy, Finland, France, Germany, Japan, South Korea, the Netherlands, Spain, Switzerland, Sweden, United Kingdom, Singapore, the United States, Taiwan and Hong Kong, and China. The industries patent data from different countries and regions in China is from the Star Patent Retrieval System of the Chinese patent information center in SIPO, from which the number of patent applications④ can be derived through retrieving countries and regions, IPC classification and time. Our sample data includes only applications for invention patents and utility model patents⑤. American patent data for different countries and regions come from the USPTO patent grant number (no application numbers are contained in this database). China

④ Due to time delay existing in the application and grant, compared with the grant data, application data can be more representative of the technology or innovation development trend.

⑤ In China, there are three types of patent: invention, utilities model and design, but it was not possible to obtain complete data for design patents.

imports trade data from different countries and regions with the industry ISIC (rev. 3) classification standard is from the STAN bilateral trade database of the OECD.

Due to import data and patent data being subject to different industrial classification standards, it is necessary to match and unify them into one classification. This paper uses the coordination method from Schmoch et al (2003) for reference, and makes the international patent classification (IPC) and industrial classification (ISIC rev. 3) respectively associated with 44 specific industries. We first classified the patent data into 44 industries, then considering the availability and completeness of the import data, we reduced the number of specific industries from 44 to 18. The industry coordination and comparison are shown in Appendix A.

### 3.3 A preliminary investigation of foreign patent applications in China

Patents application in foreign market can reflect the scale of research activities in the applicant's home nation（Eaton & Kortum, 1999. Foreign patent application in China depends on the innovation abilities of foreign inventors. As America is one of the world's most dynamic technology markets, originators of a foreign invention with great market potential will consider seeking protection in the US. Therefore, we can use the number of patent grants in the US Intellectual Property Office to represent the innovation performance of a country, which could eliminate national bias and the differences in patent systems for different countries' patent applications. Foreign patent applications in China also depend on the patent propensity of foreign inventors in China (Hu, 2010).

$$SIPO_{\mathrm{k,j,t}} = \mathrm{f}\left(USPTO_{\mathrm{k,j,t}}, \mathrm{P}^{\mathrm{C}}_{\mathrm{k,j,t}}\right) \quad (1)$$

Equation (1) is used as a model for the influence factors of foreign patenting in China, where $SIPO_{\mathrm{k,j,t}}$, $USPTO_{\mathrm{k,j,t}}$ and $\mathrm{P}^{\mathrm{C}}_{\mathrm{k,j,t}}$ are the number of patent applications in China, the number

of patent grants in the US and the patent propensity in China, respectively; *k, t* and *j* denote country, year and industry.

In fact, the foreign patent propensity in China for a country depends on several factors: the number of patent application in China including all countries and regions, the number of all countries and regions' patent grants in the US, and the number of domestic new utility patent applications in China. Since China's new patent regime came into force in 2001, reform of the patent legal system may significantly affect the foreign patent propensity. Considering the above factors, the following equation (2) is defined as log linear of equation (1).

$$\ln(SIPO_{k,j,t}) = \sum_{\substack{n=1 \\ n\neq k}}^{8} \alpha_n \ln(SIPO_{n,j,t}) + \sum_{n=1}^{8} \beta_n \ln(USPTO_{n,j,t}) + \gamma \ln(China\_U_{j,t}) + \delta\, Institution_t + \vartheta_{k,j,t} \quad (2)$$

Where, $China\_U_{j,t}$ is the number of the domestic new utility model patents applications in China, $Institution$ is an Institutional dummy variable, which takes the value one for Post-2001 (2001-2009); and zero, for pre - 2001(1995-2000). $\vartheta_{k,j,t}$ is the iid error term; *k, t* and *j* denote country, year and industry, respectively.

We select 8 countries and regions (France, Germany, Japan, South Korea, US, Taiwan, China and Finland) as our study samples, and the sample period is from 1995 to 2009. With reference to the method of Schmoch et al., (2003), we coordinate the international patent classification (IPC) and industry classification (ISIC Rev.3) together to 44 industries, that is, the value of j ranges from 1 to 44 in our paper. The analysis result of Equation (2) is shown in Table 2.

Table 2. Preliminary study of factors influencing foreign patent in China in 1995-2009

| Variables | China (1) | China_U (2) | USA (3) | Germany (4) | France (5) | Finland (6) | Japan (7) | Korea (8) | Taiwan (9) |
|---|---|---|---|---|---|---|---|---|---|
| SIPO_China | - | - | 0.193** | 0.351** | 0.084 | 0.374** | 0.156** | 0.189** | 0.08 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| China_U | - | - | -0.172** | 0.012 | 0.046 | 0.023 | 0.082** | 0.06 | 0.022 |
| SIPO_USA | 0.148** | -0.615** | - | 0.213** | 0.452** | 0.107 | 0.175** | 0.142* | 0.052 |
| SIPO_Germany | 0.281** | 0.148* | 0.138** | - | 0.204** | -0.009 | 0.213** | 0.115* | -0.184** |
| SIPO_France | 0.055 | 0.102 | 0.198** | 0.138** | - | 0.159* | 0.035 | 0.016 | 0.165** |
| SIPO_Finland | 0.086** | 0.052 | 0.02 | -0.003 | 0.067* | - | 0.023 | 0.013 | 0.095** |
| SIPO_Japan | 0.284** | 0.514** | 0.216** | 0.403** | 0.099 | 0.152 | - | 0.203** | 0.286** |
| SIPO_Korea | 0.115** | 0.153** | 0.063* | 0.078* | 0.016 | 0.032 | 0.073** | - | 0.164** |
| SIPO_Taiwan | 0.05 | 0.061 | 0.024 | -0.133** | 0.177** | 0.240** | 0.109** | 0.173** | - |
| USPTO_China | 0.152** | -0.035 | 0.032 | -0.009 | 0.049 | -0.073 | -0.062** | -0.006 | 0.065* |
| USPTO_USA | 0.429** | 0.818** | 0.509** | -0.386** | -0.051 | -0.072 | -0.217** | -0.07 | -0.053 |
| USPTO_Germany | -0.028 | 0.051 | 0.064 | 0.512** | -0.192** | -0.027 | -0.208** | -0.284** | -0.013 |
| USPTO_France | -0.012 | -0.072 | -0.070* | -0.134** | 0.393** | -0.013 | -0.028 | -0.08 | -0.161* |
| USPTO_Finland | 0.017 | 0.059 | -0.057** | 0.035 | -0.051 | 0.403** | -0.061** | -0.018 | 0.069* |
| USPTO_Japan | -0.453** | -0.585** | -0.086 | -0.129* | -0.064 | 0.017 | 0.610** | 0.139* | -0.038 |
| USPTO_Korea | -0.095** | -0.337** | -0.051 | -0.07 | 0.029 | -0.12 | 0.063* | 0.535** | -0.024 |
| USPTO_Taiwan | -0.201** | 0.608** | -0.023 | 0.104** | -0.104* | -0.074 | 0.005 | -0.051 | 0.422** |
| Institution | 0.230** | 0.251 | 0.04 | -0.134 | -0.230* | -0.081 | 0.266** | -0.199* | 0.482** |
| Obs. | 645 | 645 | 645 | 645 | 645 | 645 | 645 | 645 | 645 |
| R square | 0.889 | 0.745 | 0.917 | 0.879 | 0.864 | 0.716 | 0.946 | 0.89 | 0.878 |

Note 1: SIPO_USA represents US patent applications in the China Patent Intellectual Property Office. USPTO_USA represents the US patent grant in the United State Patent and Trademark Office. The corresponding variables of other countries and regions are similar.

The data for 44 industries is incomplete; we only have data for 43 industries here.

Note 2: ** significant at 5% level; * significant at the 10% level.

The first two columns of Table 2 shows that the domestic invention patents in China have a significantly positive relationship with most foreign patent applications (such as USA, German, Finland, Japan and South Korea) in China, but domestic new utility model patents are positively and significantly related with Japan and South Korea. The third to the tenth columns of Table 2 finds that most foreign countries' and regions' patent applications are significant positively related with domestic patent applications in China. Furthermore, except Finland, foreign countries patent applications in China are also correlated with each other. Table 2 also shows the correlation between patent application in China and patent grants in the USA for the eight

countries and regions. There is a competitive trade-off relationship among the eight countries and regions in US patent grants (a significant negative correlation), such as America and Finland, Germany and France, and Japan with America and Germany, which shows the intense competition in the global patent market. From the lower left diagonal position in the table, for all countries including China, their patent application in China is significantly correlated with their patent grant in USA, and the elasticity of most countries (except China) is around 0.5. Patent grant in America to a great extent indicates a country's innovation abilities, and thus the self-innovation of a country is an important impetus supporting foreign patent activities. It is worthwhile to note that, although Chinese patent application is significantly correlated with patent grant in US, the value of 0.152 is far less than that of the other countries.

Next, we investigated a longer period of 1986-2009 and the results appear in Appendix B. The results show an obvious influence of the institutional variable, which significant impacts for China, USA, Japan and Taiwan. In July 2001, before China joined the WTO, China's second amendment of the patent law came into force, which broadened the scope of patent protection and strengthened enforcement mechanism. Compared with the empirical results of 1995-2009, the results of other variables are the same generally, with only a few differences. A possible reason for the difference may be the position of South Korea. South Korean patent applications in China ranked fourteenth in the period of 1986-1992, but leaped to fourth in the period of 1993-2001. Therefore, the result covering the two periods may be more complex.

## 4. Empirical analysis

On the basis of the preliminary study, the following part is to test whether the market covering

hypothesis or competition threat hypothesis is supported, investigating whether the threat of participation and competition in Chinese market decides foreign patenting behavior. Hu (2010) replaced the degree of participation and competition of different countries and regions in the Chinese market with Chinese import industry data, this indicator views the Chinese market as the final export destination. Similarly, we differentiate the import data into two categories: one is $Import_{k,j,t}$, representing China's total imports from foreign industry, where k, j, t again denote country, industry, and year respectively. The other is $Other\_import_{k,j,t}$, representing China's total imports for all countries and regions except country k. Further, $Other\_import_{k,j,t}$ is measured by two different indicators. One is $TI_{k,j,t}$, representing China's total un-weighted imports for all the other countries and regions except country k; the second is $CI_{k,j,t}$, representing China's total weighted imports for all the other countries and regions except country k, with the weight $TP_{k,l,j,t}$, where $TP_{k,l,j,t}$ is the technology proximity (TP) between country k and country l that exports to China in an industry-year. The technology proximity between two foreign industries is computed as an un-centered correlation between the patent distributions over 44 industries. The definitions of $TI_{k,j,t}$ and $CI_{k,j,t}$ are shown in Equation (3) and Equation (4) respectively.

We consider the competition in Chinese import market, as well the patent market. According to the results from Table 2, we take the number of a foreign country's patent grants in USPTO ($USPTO_{k,j,t}$), the number of domestic invention patent applications in China ($Pc_{j,t}$), and the number of domestic new utility patent applications ($Utility_{j,t}$) in China as the independent variables. Considering the prevailing competition between countries and regions in the Chinese

market, we also include the total number of patents from the other countries and regions except country k ($Other\_sipo_{k,j,t}$) as an independent variable in the model. Because the technology development is mostly accumulative and path-dependent, the level of patent application in China may depend on its previous level. We therefore introduce the first order lag term to extend the model to be a dynamic model, in order to prevent the setting bias and error of the basic model. The complete dynamic panel of the log linear model is shown as Equation（5）.

$$\mathrm{TI}_{k,j,t} = \sum_{l \neq k} \mathrm{Import}_{l,j,t} \qquad (3)$$

$$\mathrm{CI}_{k,j,t} = \sum_{l \neq k} \mathrm{TP}_{k,l,j,t}\mathrm{Import}_{l,j,t}\ ,\ \ \mathrm{TP}_{k.l.j.t} = \left(V'_{k,j,t}V_{l,j,t}\right) / \left(\sqrt{V'_{k,j,t}V_{k,j,t}}\sqrt{V'_{l,j,t}V_{l,j,t}}\right) \qquad (4)$$

$$\ln(\mathrm{SIPO}_{k,j,t}) = \alpha + \beta_0 \ln \mathrm{SIPO}_{k,j,t-1} + \beta_1 \ln(\mathrm{Import}_{k,j,t}) + \beta_2 \ln(\mathrm{Other\_import}_{k,j,t}) + \beta_3 \ln(\mathrm{Other\_sipo}_{k,j,t}) + \beta_4 \ln(\mathrm{USPTO}_{k,j,t}) + \beta_5 \ln(\mathrm{Pc}_{j,t}) + \beta_6 \ln(\mathrm{Utility}_{j,t}) + \beta_7\ \mathrm{Institution}_t + \mu_{k,j,t} \qquad （5）$$

Where, k, j and t again denote country, industry, and year respectively. $V_{k,j,t}$ is a vector of patent class shares of country k's SIPO patent applications in year t and k is 19 countries and regions (not including China), the time period ranges from 1995 to 2008, and the value of industry j ranges from 1 to 18, as shown in Appendix A. The institutional dummy variable $\mathrm{Institution}_t$ is defined as in Equation (2). $\mu_{k,j,t}$ is the error term.

Equation (5) is a dynamic panel model, and the lag of the dependent variables is related with the fixed effects of non-observed individual country in this model, which leads to the result of the pooled OLS estimation and fixed effects estimation being biased. Arellano & Bond (1991) provide an alternative way to estimate equation (5), which is difference-GMM. The basic estimation strategy is to assume that the error term in equation (5) satisfies:

$$\mathrm{Cov}(\mu_{k,j,t}, \mu_{k,j.t-1}) = 0, \mathrm{Cov}(\Delta\mu_{k,j,t}, \Delta\mu_{k,j.t-1}) \neq 0, \mathrm{Cov}(\Delta\mu_{k,j,t}, \Delta\mu_{k,j.t-m}) = 0, m \geq 2$$

Where $\Delta\mu_{k,j,t} = \mu_{k,j,t} - \mu_{k,j,t-1}$.

Table 3 provides a number of diagnostic statistics to verify the validity of the model and the instruments. We use all lags that are more than two periods old as instruments for the first differences. The Sargan over-identification test indicates we are unable to reject the null hypothesis that the instruments are collectively valid at the 5% significance level. By model construction and assumption, the error terms are correlated to the first order, but not the second order, the AR (1), AR(2) and AR(3) test statistics confirm this at the 1% significance level.

The results of GMM estimation in Table 3 show that China's imports from a country have a significant negative impact on the patent application of that country in China. This is different from the expectation of the market share hypothesis. A possible explanation is that a strong market power brought with a large market share reduces the competition, hence reducing patent activities in China, which probably supports the competitive threat hypothesis. The total imports that China imports from other countries (the competitive nations) except country k, have a significant positive impact on country k's patent applications in China, no matter whether the total imports are weighted based on the technological similarity with the patent classified technology measurement in the two countries. The influence coefficient is higher when considering the weighted factor of competition in the same industry. The findings all directly support the competition threat hypothesis. Patent grants in the USA and the patent applications of other competitive countries in China, significantly positively influence each

other. This supports our previous analysis. It is worthwhile to note that domestic invention patent applications in China did not significantly affect the patent behavior of foreign countries, and domestic new utility patent applications in China had a significant negative effect. From a dynamic perspective, taking all the factors into account, increase in domestic new utility model patent applications in China actually means a lower level of substantial competition in the patent market, thus weakening the foreign patent activity in China. The reform of the patent system in China has a significant positive effect on foreign patent applications in China. This is consistent with the conclusion of some other literature. As expected, patent applications in China have a significant positive associated with previous impact on the last year's patent applications. From results of dynamic GMM model, it can be seen the competitive threat hypothesis is verified, whereas the market covering hypothesis is not supported.

For comparison purpose, we also use a fixed effects panel data model to estimate equation (5), without considering the patent application time accumulation and path-dependence, considering only the fixed effects of country and time there is no need to consider the effect of the specific reform of the patent system in China now. The empirical results are reported in Table 3. The Hausman test confirms that we should reject the random effect model and accept the fixed effect model. We find these results are consistent with the estimation result of a dynamic GMM, differing only in significance, namely, the market covering hypothesis does not hold.

Table 3. The influence factors of foreign patent application in China

| | **GMM model** | | **Fixed- effects model** | | | |
|---|---|---|---|---|---|---|
| **Variables** | **model(1）** | **model(2)** | **model(3)** | **model(4)** | **model(5）** | **model(6）** |

| | | | | | | |
|---|---|---|---|---|---|---|
| Constant | 0.070*** (0.000) | 0.071*** (0.000) | 2.726*** (0.000) | 2.749*** (0.000) | 3.770*** (0.000) | 3.832*** (0.000) |
| first-order lag dependent variable ($\ln SIPO_{kj,t-1}$) | 0.329*** (0.000) | 0.330*** (0.000) | 0.401*** (0.000) | 0.402*** (0.000) | - | - |
| imports of China from a country $\ln(Import)$ | -0.041*** (0.000) | -0.040*** (0.000) | -0.002 (0.799) | -0.001 (0.932) | -0.002 (0.797) | -0.004 (0.564) |
| total weighted imports of China form other competition countries (ln(CI)) | 0.073*** (0.000) | - | 0.086*** (0.000) | - | 0.143*** (0.000) | - |
| total imports without weighted that China from other competition countries (ln(TI)) | - | 0.068*** (0.000) | - | 0.076*** (0.000) | - | 0.125*** (0.000) |
| The number of foreign patent authorization in America (Ln(USPTO)) | 0.137*** (0.000) | 0.136*** (0.000) | 0.212*** (0.000) | 0.211*** (0.000) | 0.394*** (0.000) | 0.395*** (0.000) |
| The number of domestic patent invention applications in China(Ln(Pc)) | 0.0004 (0.879) | 0.0005 (0.862) | 0.079*** (0.007) | 0.077** (0.010) | 0.127*** (0.000) | 0.122*** (0.000) |
| total number of other competition country's patent applications in China ($\ln(Other\_sipo)$ ) | 0.338*** (0.000) | 0.337*** (0.000) | 0.050 (0.287) | 0.057 (0.227) | 0.034 (0.471) | 0.044 0.349 |
| The number of new utilization patent applications of China( ln(Utility)) | -0.057*** (0.000) | -0.057*** (0.000) | -0.3*** (0.000) | -0.292*** (0.000) | -0.388*** (0.000) | -0.366*** (0.000) |
| The dummy variables of Chinese patent system reform (Institution) | 0.017*** (0.000) | 0.016*** (0.000) | - | - | - | - |
| Country effects and time effects | - | - | significant | significant | significant | significant |
| Sargan test | 328.24 (0.4086) | 327.41 (0.4212） | - | - | - | - |
| AR(1) | -4.61 (1.000) | -4.61 (1.000) | - | - | - | - |
| AR(2) | 1.78** (0.0449) | 1.78** (0.0447) | - | - | - | - |
| AR(3) | 0.03 (0.4873) | 0.05 (0.4808) | - | - | - | - |
| Hausman test | - | - | 1390.7*** (<0.001) | 1382.7*** (<0.001) | 128.91*** (<0.001) | 127.55*** (<0.001) |
| Model selection | - | - | Fixed effect | Fixed effect | Fixed effect | Fixed effect |
| R square | - | - | 0.9875 | 0.9875 | 0.9839 | 0.9838 |
| Obs. | 4446 | 4446 | 4446 | 4446 | 4788 | 4788 |

Note 1: p-values in parentheses. *** Significant at the 1% level; ** significant at the 5% level;* significant at the 10% level.

Note 2: Estimates of country dummies and time dummies are not reported but they are available on request.

The results in Table 3 show, on the one hand, that the fierce competition among foreign counter's for sales in the Chinese market explains the foreign propensity to patent in China; the larger the sales of competitor countries in China, the more incentive there is for foreign patent activity in China. Foreign patenting in China is strategic preemption behaviour for preventing and impeding the competitors, which may hinder technology spillovers, in contrast to the market covering hypothesis with a large amount of new invention technology introduced

in the Chinese market. As mentioned earlier, the immaturity of China's proprietary system makes the protection of patents limited. What need to be more considered in patent application in China, are competitors (from China and other countries) in the Chinese market, rather than imitators. Faced with the competitors' patent behaviour and innovation in the China market and the world market, foreign firms had to implement the same strategy to ensure the freedom of their business operation. Once a competitor has patented a technological innovation, this will prevent others from implementing control of technology innovation; further, it will affect the business operation freedom and strategic choice. This has been verified in the company level analysis. The consideration of business operation freedom will outweigh the imitation risk, especially for those companies that have advantages in technology (Keupp et al., 2012).

On the other hand, there is similar competition in the Chinese patent market: the more the competitors of one country's patents in China, the more that country will patent in China. The high influence coefficient (close to 0.34) explains the competition or the following behavior deciding the increasing foreign propensity to patent in China.

At the same time, the decision is path- dependent, and has a significant relation with previous patent applications in China. In the dynamic view, the influence of domestic patent applications in China on foreign patent applications is positive, although it is not significant; From the result of parameter estimation on the static fixed effect model, the influence is significantly positive, indicating that there exists another competition threat in the Chinese patent market apart from the competition threat hypothesis in the Chinese sales markets, both of them can explain the phenomenon of the surge in foreign patenting in China.

## 5. Extended discussion

The main foreign patent applicants in China are foreign subsidiaries, and the trend and structure of competition in the Chinese sales market and patent market force them to implement the patent behavior, to drive the efficient interaction of these two markets to maintain a competitive advantage. Does foreign patent surge in China really mean more technology spillovers in local market? Liu and Ma (2012) measured the technology spillovers effect of multinational corporation patents in China during three periods in relation to the technology gap and the extent of competition. The results show that the technology spillovers to Chinese enterprises are decreased in a highly competitive market. The model of foreign patent spillovers transferring constructed by Zhang (2010) also suggests that foreign patent application spills little technology into the competitive eastern region. We try to characterize the competition situation in the patent market by the similarity of patent technology, judging whether the potential effect brought by patent market competition is consistent with the conclusion of technology spillover, which is promoted by the sales market competition.

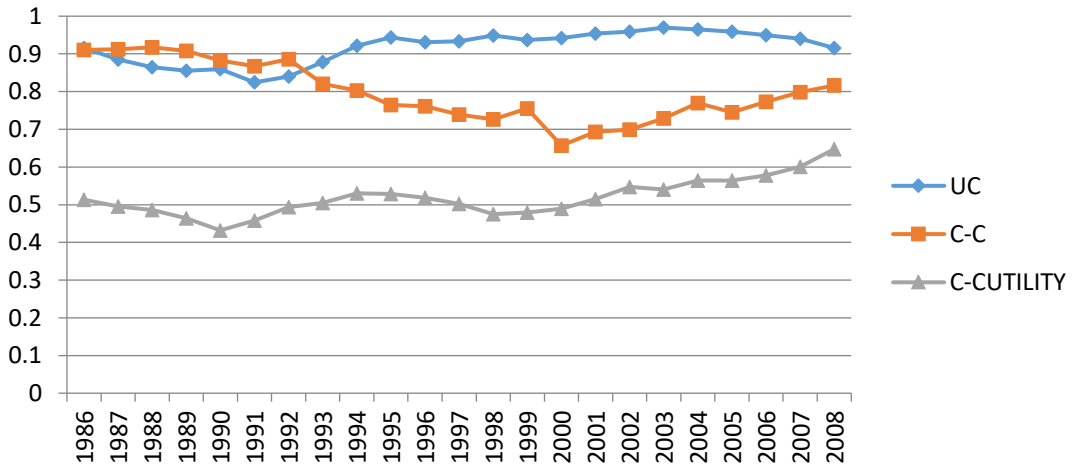
The method of measuring the technology similarity is extended by the construction of a vector of technology similarity between countries (Jaffe 1986,1989), adopting about 400 original patents classified by the USPTO as the dimension of technology vector, which yields a low value of similarity result (Jaffe, 1989). Guo et al. (2007) use the R&D data instead of the patent data of Jaffe's equation to construct the technology vector of 13 manufacturing sub-industries; the value of similarity result is higher. From experience, the appropriate spatial vector dimension to measure the national technology similarity is between 30 and 50. Therefore, based on the method of Jaffe (1986) and Trajtenberg (1999), we construct 44

technology vectors according to the industry classification from Schmoch et al.（2003）, to measure the patent technology similarity Tprox between several main developed countries, as shown in formula (6).

$$Tprox_{i,j,t} = \sum_{n=1}^{44} f_{n,i,t} f_{n,j,t} \Big/ \sqrt{\left(\sum_{n=1}^{44} f_{n,i,t}^2\right)\left(\sum_{n=1}^{44} f_{n,j,t}^2\right)} \qquad (6)$$

Where, $f_{n,i,t}, f_{n,j,t}$ are the share of patents that country i and country j distributed to industry n in year t, respectively. The greater the overlaps of the patent distribution vector between two countries, the greater the technology similarity between two countries. If two vectors are orthogonal, the value is zero; if the two vectors are identical, the value is 1. Figure 1 shows the tendency chart of three groups of technology similarity in 1986-2008, namely UC (the technology similarity of foreign patent grants in US and patent applications in China), C-C (the technology similarity of foreign patent applications in China and Chinese domestic invention patent applications) and C-CUTILITY (the technology similarity of foreign patents application in China and Chinese domestic new utility patent applications).

Figure 1 The tendency chart of technology similarity of three groups of from 1986-2008




Source: SIPO, USPTO. Author's calculations

As Figure 1 shows, in the early years, compared with UC, C-C was much bigger, which reflects selection of technology closer to the Chinese market when foreign firms entered China early. Then, C-C fluctuates a little but the overall tendency is downward. From 1986 to 2001, C-C tends to decline, which means that the technology difference in patents between China and foreign countries was increasing. In fact, it is beneficial to obtain new external technology. Generally speaking, large technology similarity will help countries absorb technology from each other. At the same time, there will be fewer opportunities for achieving new technology owing to their much greater reliance on each other. In the same period of 1989-2001, UC increased steadily, reaching the maximum value in 2002, indicating that the self-innovation of foreign countries strongly supported their patent applications in China. From 2002, UC gradually declined slightly again, and the technology difference between China and the USA is widened slightly. Almost simultaneously, C-C declined to a minimum, and then rose steadily. The increasing C-C reflects foreign enterprises' well-understanding of the Chinese market with further entry and technology integration, which makes the patent technology distribution and development closer to domestic enterprise in China; but at the same time, the increase in technology similarity is not good in term of the opportunity for access to new external technology, such as the new technology in the US market. In addition, although C-CUTILITY is the weakest (around 0.5), the whole structure tendency is rising continually. The new utility patent is not unique to China; it is well recognized that the utility patent is inferior to the invention patent in terms of innovation (Kim et al., 2012). Therefore, the increase C-C in China is not a good signal for China.

The analysis of technology similarity shows that the surge of foreign patents in China does not mean more opportunities for access to and acquirer of foreign advanced technology; on the contrary, the technology spillover is limited. Will the further strengthening competition of foreign countries in the Chinese goods market and patent market bring a reverse of technology similarity in favor of technology spillovers? This needs more evidence and analysis before a judgment can be formed.

## 6. Conclusion

The surge of foreign patenting in China leads us to consider two questions: Why are foreign countries enthusiastic to patent in China? Does this mean that more foreign technology in China has been spilled over the local market? We selected data from the China Intellectual Property Office and the United States Patent and Trademark Office separately (1985-2009), using industry level data from 19 countries and regions to inspect the market covering and competition threat hypotheses in China. The results shows that the competition between different foreign countries in the Chinese sales market and patent market support the competition threat hypothesis. In other words, foreign patent applications in China depend on the market decision and patent decision of competitor countries. In addition, foreign patent applications in China are related with its capacity of technology innovation, and also influenced significantly by the reform of the Chinese patent system. Furthermore, the extended discussion shows that the technology similarity of patents in both China and foreign countries improved greatly around 2001. It is easy for different countries to absorb technology by high technology similarity with each other. Meanwhile, the technology difference of foreign

countries in the Chinese market and American market has been widened slightly. The increase of foreign applications in China does not mean more opportunities for China to access and obtain new technology from foreign countries. On the contrary, the technology spillover is limited.

## Appendix A. Industry classification

| 18 industries in our paper | M.L. Mancusi 22 industries | ISIC Rev.3 | Schmoch et al. 44 industries | Content |
|---|---|---|---|---|
| 1 | 1 | 15 | 1 | Food, beverages |
| | 2 | 16 | 2 | Tobacco products |
| 2 | 3 | 17 | 3 | Textiles |
| | 4 | 18 | 4 | Wearing apparel |
| | 5 | 19 | 5 | Leather articles |
| 3 | 6 | 20 | 6 | Wood products |
| 4 | 7 | 21 | 7 | Paper |
| - | - | 22 | 8 | Publishing and printing |
| 5 | 8 | 23 | 9 | Petroleum products, nuclear fuel |
| 6 | 9 | 24-2423 | 10 | Basic chemical |
| | | | 11 | Pesticides, agro-chemical products |
| | | | 12 | Paints, varnishes |
| 7 | 10 | 2423 | 13 | Pharmaceuticals |
| 6 | 9 | 24-2423 | 14 | Soaps, detergent, toilet preparations |
| | | | 15 | Other Chemicals |
| | | | 16 | Man-made fibres |
| 8 | 11 | 25 | 17 | Rubber and plastics products |
| 9 | 12 | 26 | 18 | Non-metallic mineral products |
| 10 | 13 | 27 | 19 | Basic metals |
| 11 | 14 | 28 | 20 | Fabricated metal products |
| 12 | 15 | 29 | 21 | Energy machinery |
| | | | 22 | Non-specific purpose machinery |
| | | | 23 | Agricultural and forestry machinery |
| | | | 24 | Machine-tools |
| | | | 25 | Special purpose machinery |
| | | | 26 | Weapons and ammunition |
| | | | 27 | Domestic appliances |
| 13 | 16 | 30 | 28 | Office machinery and computers |
| 14 | 17 | 31 | 29 | Electric motors, generators, transformers |
| | | | 30 | Electric distribution, control, wire, cable |
| | | | 31 | Accumulators, battery |
| | | | 32 | Lightening equipment |
| | | | 33 | Other electrical equipment |
| 15 | 18 | 32 | 34 | Electronic components |
| | | | 35 | Signal transmission, telecommunications |
| | | | 36 | Television and radio receivers, audiovisual electronics |
| 16 | 19 | 33 | 37 | Medical equipment |
| | | | 38 | Measuring instruments |
| | | | 39 | Industrial process control equipment |
| | | | 40 | Optical instruments |
| | | | 41 | Watches, clocks |
| 17 | 20 | 34 | 42 | Motor vehicles |
| 18 | 21 | 35 | 43 | Other Vehicles |
| - | 22 | 36 | 44 | Furniture, consumer goods |

## Appendix B. Preliminary study of factors influencing foreign patent applications in China in 1986-2009

| variables | China (1) | China_U (2) | America (3) | Germany (4) | France (5) | Finland (6) | Japan (7) | Korea (8) | Taiwan (9) |
|---|---|---|---|---|---|---|---|---|---|
| SIPO_china | - | - | 0.243** | 0.238** | 0.016* | 0.205** | 0.044 | -0.045 | 0.180** |
| China_U | - | - | -0.162** | 0.052* | 0.013 | 0.013 | 0.050* | -0.071* | -0.016 |
| SIPO_USA | 0.207** | -0.339** | - | 0.218** | 0.324** | 0.170** | 0.208** | 0.198** | 0.097 |
| SIPO_Germany | 0.209** | 0.199** | 0.129** | - | 0.249** | -0.019 | 0.324** | 0.116** | -0.071* |
| SIPO_France | 0.066** | 0.052 | 0.142** | 0.184** | - | 0.135** | 0.099** | 0.011 | 0.047 |
| SIPO_Finlnd | 0.070** | 0.047 | 0.042** | -0.008 | 0.077** | - | 0.053** | 0.052 | 0.100** |
| SIPO_Japan | 0.076* | 0.154** | 0.167** | 0.443** | 0.183** | 0.172** | - | 0.232** | 0.079 |
| SIPO_Korea | -0.037 | -0.086** | 0.066** | 0.066** | 0.008 | 0.07 | 0.096** | - | 0.398** |
| SIPO_Taiwan | 0.078** | 0.027 | 0.033 | -0.041 | 0.036 | 0.138** | 0.033 | 0.407** | - |
| USPTO_china | 0.090** | -0.099** | 0.015 | 0.005 | 0.083** | 0.087* | -0.03 | 0.055 | -0.004 |
| USPTO_USA | 0.478** | 0.917** | 0.517** | -0.386** | 0.044 | -0.112 | -0.157** | 0.041 | -0.185** |
| USPTO_Germany | -0.171** | -0.358** | -0.026 | 0.524** | -0.096 | 0.184* | -0.195** | -0.167** | -0.024 |
| USPTO_France | -0.086* | -0.069 | -0.029 | -0.107** | 0.329** | -0.128* | 0.007 | -0.182** | -0.044 |
| USPTO_Finland | 0.063** | 0.091** | -0.071** | 0.023 | -0.041 | 0.377** | -0.056** | -0.055 | 0.113** |
| USPTO_Japan | -0.103** | -0.155** | 0.04 | -0.165** | -0.095* | -0.191** | 0.410** | -0.143** | -0.181** |
| USPTO_Korea | -0.054** | -0.163** | -0.03 | -0.057 | 0.002 | -0.085 | 0.072** | 0.550** | -0.005 |
| USPTO_Taiwan | -0.155** | 0.663** | -0.069** | 0.041 | -0.086* | -0.034 | 0.043 | -0.022 | 0.511** |
| Institution | 0.484** | 0.588** | 0.165* | -0.087 | -0.084 | 0.065 | 0.410** | -0.199 | 0.397** |
| Obs. | 1032 | 1032 | 1032 | 1032 | 1032 | 1032 | 1032 | 1032 | 1032 |
| R square | 0.823 | 0.738 | 0.898 | 0.867 | 0.834 | 0.705 | 0.911 | 0.864 | 0.846 |

Note 1: SIPO_USA represents the American application in Chinese intellectual Property Office, USPTO_USA represents the American patent authorization in America patent and Trademark Office. The definition of corresponding variables is similar in other countries and regions.

Note 2: ** significant at 5% level;* significant at the 10% level.

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